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Vercaemer et al.

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[54] **METHOD AND APPARATUS FOR CEMENTING A WELL**

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[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

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[51] **Int. Cl.**[7] **E21B 23/08**

[52] **U.S. Cl.** **166/277**; 166/285; 166/177.4; 166/207

[58] **Field of Search** 166/277, 285, 166/380, 177.4, 207

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[57] **ABSTRACT**

A method of cementing a well permitting a reduction in the degree of diameter reduction of casing or liners required, and not requiring excessively large initial conductor casing, is described. The method is characterized by provision of an enlarged wellbore and a novel liner structure which is adapted for expansion of a reduced diameter section thereof downhole, providing, before expansion of the section, unimpeded flow of fluid from the enlarged wellbore during cementing and close fit of the expanded section with the casing or preceding liner, after cementing is completed and expansion of the section. A novel well liner structure and novel well liner expansion means are disclosed.

12 Claims, 3 Drawing Sheets

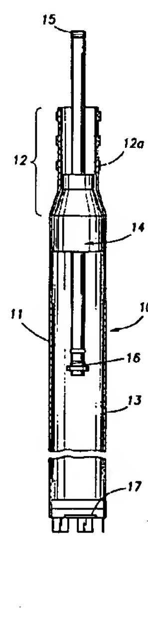


FIG. 1
(PRIOR ART)

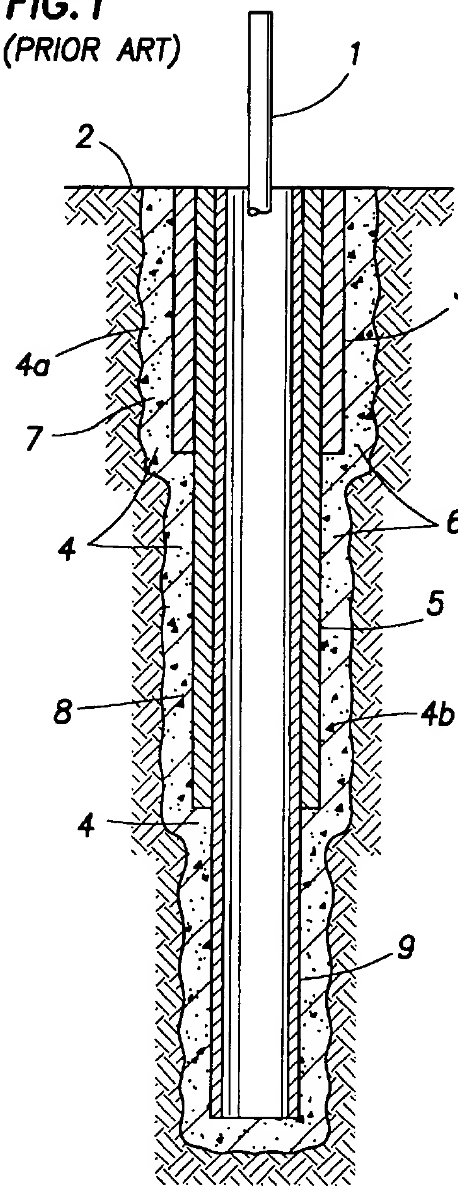


FIG. 2

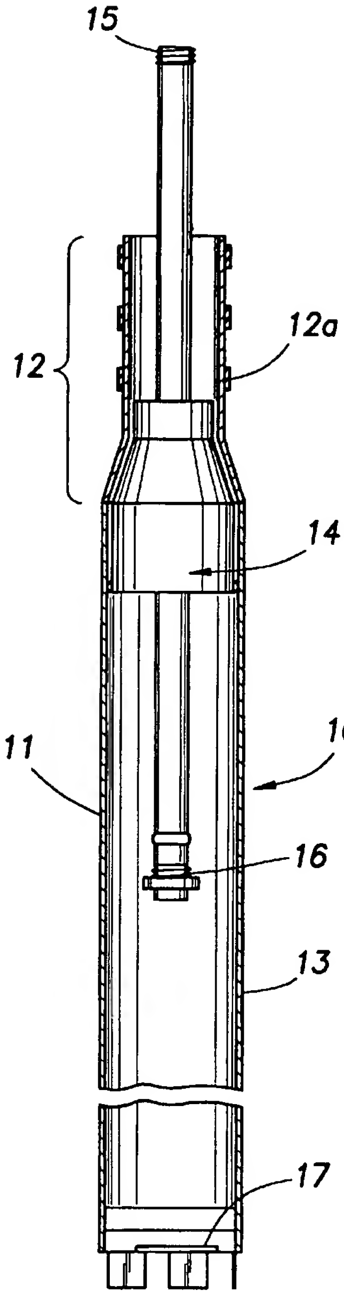


FIG.3

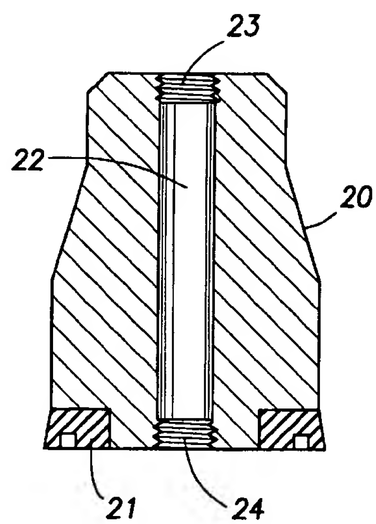
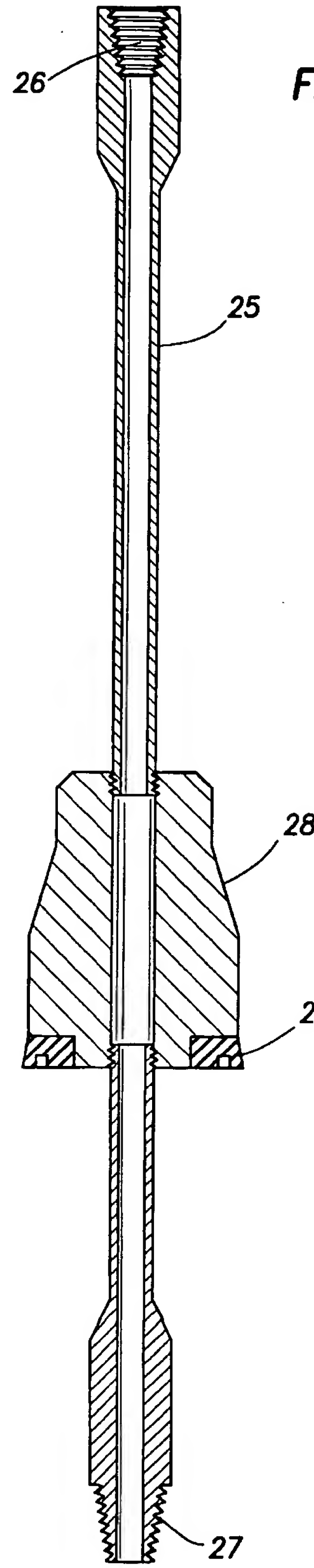


FIG.4



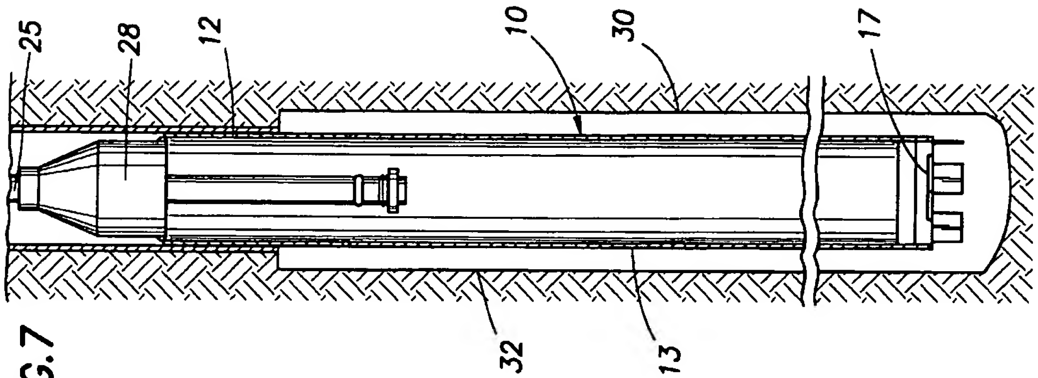


FIG.7

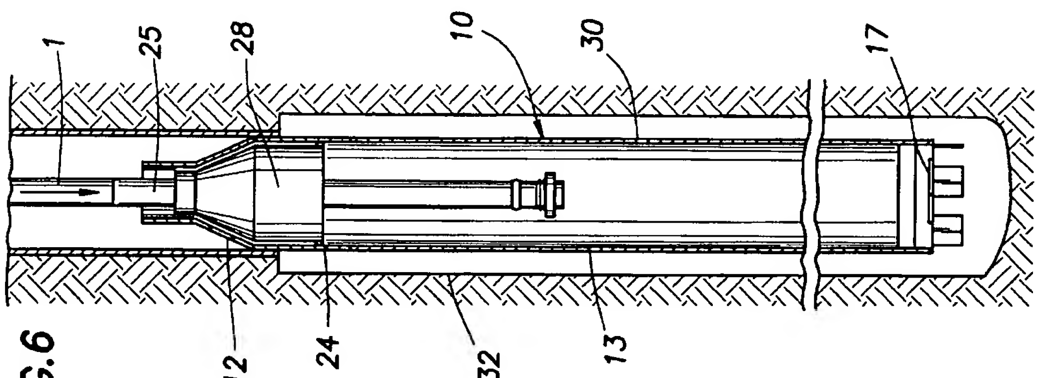


FIG.6

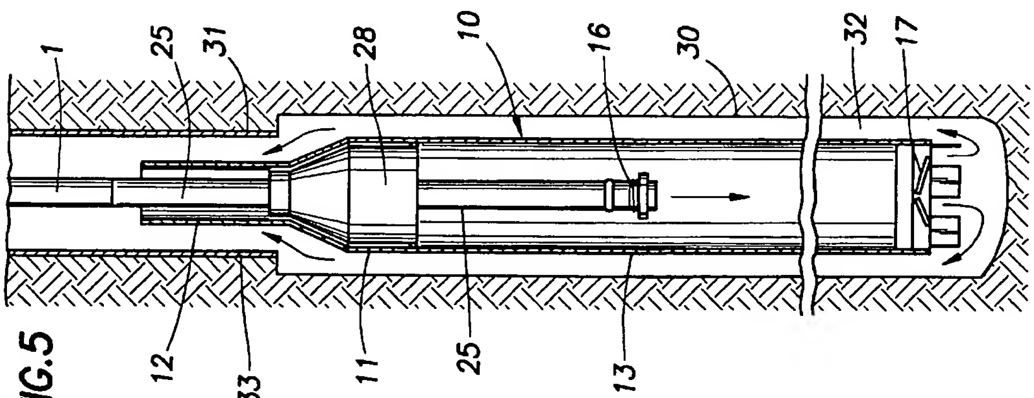


FIG.5

METHOD AND APPARATUS FOR CEMENTING A WELL

FIELD OF THE INVENTION

This invention relates to a method for cementing a well and to apparatus useful in well cementing operations.

BACKGROUND OF THE INVENTION

In the conventional drilling of a well, such as an oil well, a series of casings and/or liners are commonly installed sequentially in the wellbore or borehole. In standard practice, each succeeding liner placed in the wellbore has an outside diameter significantly reduced in size when compared to the casing or liner previously installed. Commonly, after the installation of each casing or liner, cement slurry is pumped downhole and back up into the space or annulus between the casing or liner and the wall of the wellbore, in an amount sufficient to fill the space. The cement slurry, upon setting, stabilizes the casing or liner in the wellbore, prevents fluid exchange between or among formation layers through which the wellbore passes, and prevents gas from rising up the wellbore.

The use of a series of liners which have sequentially reduced diameters is derived from long experience and is aimed at avoiding problems at the time of insertion of casing or liner installation in the wellbore. The number of liners or casings required to reach a given target location is determined principally by the properties of the formations penetrated and by the pressures of the fluids contained in the formations. If the driller encounters an extended series of high pressure/low pressure configurations, the number of liners required under such circumstances may be such that the well cannot usefully be completed because of the continued reduction of the liner diameters required. Again, a further problem of the standard well liner configuration is that large volumes of cuttings are produced initially, and heavy logistics are required during early phases of drilling.

While several approaches to the resolution of these problems have been attempted, none have proven totally satisfactory. Accordingly, there has existed a need for a well lining and cementing technique or procedure, and means to carry it out, which would eliminate or significantly reduce the degree of diameter reduction required when a series of well liners must be inserted. The invention addresses this need.

SUMMARY OF THE INVENTION

There is thus provided, in one embodiment, a method or process, useful in cementing a well, especially a hydrocarbon well, which is characterized by the use of increased external and internal diameter liners, i.e., by a reduction in the degree of diameter reduction of the liners required, and which does not require excessively large initial conductor casing or surface pipe. Accordingly, in this embodiment, the invention relates to a method of cementing a wellbore in which a casing or first liner is provided in a wellbore. (As utilized herein, the terms "first" and "second", etc., in relation to the casing or liners mentioned, are relative, it being understood that, after the initial "second" casing or liner is cemented, it may become a "first" liner for the next cementing operation as such operations proceed down the wellbore.)

Further drilling operations are then conducted to provide an enlarged wellbore. As used herein, the term "enlarged wellbore" refers to a wellbore or borehole having a diameter

greater than that of the internal diameter of the casing or preceding liner, preferably greater than the external diameter of the casing or preceding liner, such a wellbore being provided or drilled in a manner known to those skilled in the art, as described more fully hereinafter. At a desired depth, or when it is otherwise decided to line and cement the enlarged wellbore, a second liner, whose greatest external (outside) diameter approximates, i.e., is only slightly smaller than the internal diameter of the casing or first liner provided, is then provided in the enlarged wellbore through the casing or first liner. The second liner comprises a minor section or segment of significantly or further reduced external and internal diameter (in relation to the remaining or remainder segment of the second liner) and is composed, at least in said minor section, of a deformable liner material. According to the invention, the second liner is positioned in relation to the enlarged wellbore so that the section of reduced external diameter is located or positioned in the lower portion of the casing or first liner and the remainder segment below the lower portion, in such manner that fluid may circulate freely, i.e., without substantial or significant impediment, in the annuli formed by the second liner and the enlarged wellbore and the internal wall of the casing or first liner.

Inside the bore of the larger remaining or remainder segment of the second liner there is disposed or provided, as more fully described hereinafter, a movable, fluid tight die member of appropriate dimensions, preferably positioned in the second liner distant from the bottom of the remainder segment and proximate the minor section of reduced external and internal diameter, and which, after initial positioning or installation in the enlarged wellbore, is fixed in relation to said wellbore. As utilized herein, the phrase "fluid tight", in reference to the die member, is understood to indicate that the die member is appropriately sized and shaped and contains appropriate sealing means to prevent significant passage of fluid, even under substantial pressure, as described hereinafter, past its periphery or circumference which is contiguous to the interior wall or bore of the remainder segment of the second liner. The fluid tight die member, including the sealing means, is further a component or element of the novel die-expansion assembly of the invention which comprises means for transmitting a fluid to the bore of a liner, and means for connecting the die member to a drillstring. The latter means are important in positioning the novel liner-die assembly in the enlarged wellbore initially, as described more fully hereinafter, and in responding to applied fluid pressure. As utilized herein, the term "drillstring" is understood to include tool members or collars, etc., normally utilized in wellbore operations. In the specific context of the invention, the die-expansion assembly comprises means for transmitting a fluid to the bore of the remainder segment of the second liner, to the end that a fluid under significant pressure may be applied to the bore of the remainder segment of the second liner, and further comprises means for connecting the die member to a drillstring.

According to the method of the invention, upon proper positioning of the liner-die assembly of the invention in the wellbore, cement slurry is then pumped down the drillstring through the casing or first liner and the second liner (via the means for transmitting a fluid) and into the enlarged wellbore annulus in an amount sufficient to cement the wellbore annulus. After the cement is in place, the bottom or bottom end of the second liner is sealed, by standard techniques known to those skilled in the art, to prevent egress of fluid from the liner. As utilized herein, reference to the "bottom"

or "bottom end" of the liner is to be construed as referring to a site downhole on or in the liner rather than as a precise location of the liner body. The sealing of the bottom end of the liner, coupled with the seal provided by the fluid tight die member, provides or constitutes, assuming a location of the die member removed or distant from the bottom of the liner, and, with the exception of communication with the aforementioned means for transmitting a fluid, a sealed compartment or recess in the bore of the remainder segment of the second liner. Substantial fluid pressure is then applied to the interior of this sealed remainder segment recess by pumping a fluid, e.g., a wellbore fluid such as a drilling fluid or a spacer fluid, through said means for transmitting a fluid which communicates with the compartment or recess. As fluid under pressure is introduced into the otherwise sealed recess, the increasing pressure therein tends to force the fluid tight die member up the second liner bore. According to the invention, as fluid pressure is increased in the sealed recess, the position of the die-expansion assembly, including the die member, is mechanically adjusted or allowed to adjust by translation upward in the liner (and the wellbore). The rate of upward adjustment or movement of the die-expansion assembly by upward movement of the running string and the application of pressure to the second liner bore recess are correlated so as to produce movement of the die member up through the section of reduced diameter with concurrent gradual deformation and expansion of the section of reduced diameter, providing an expanded section or segment having an external diameter equal to or approximating, preferably slightly greater or larger than that of the remainder segment of the second liner, as described more fully hereinafter. The expansion of the section provides an external diameter for the section which more closely approximates the internal diameter of the casing or first liner, while providing a larger flow passage internally for production fluids. Continued application of fluid pressure and correlated upward translation or adjustment of the position of the die-expansion assembly frees the die member from the second liner, the second liner then being positioned or allowed to remain with a substantial minor portion of the newly expanded segment in the casing or first liner. The cement slurry in the wellbore annulus is then allowed to set.

In yet further embodiments, the invention relates to a novel liner, which may additionally include expansion means therein; to an apparatus or tool for expansion of a liner having a reduced diameter section; and to a novel liner-die assembly or combination which is useful in cementing operations. More particularly, the liner of the invention comprises a wellbore liner having a minor section of reduced external and internal diameter composed of a deformable material and a larger remainder section of increased external and internal diameter. The expansion device or apparatus of the invention comprises unique fluid tight die means adapted for expansion of a liner section of reduced internal and external diameter, and preferably comprises a means for transmitting a fluid, e.g., a pipe; a die member adapted for expanding, at least substantially uniformly, the bore of a liner, on the periphery of said pipe; and sealing means positioned on the periphery of the die member adapted to provide a fluid tight seal between the bore of a liner and said die member. In the preferred arrangement, the pipe is provided at one end thereof with means for connecting the pipe to, or for suspending the pipe from, a drillstring, and is further preferably provided at the opposite end thereof with means for suspending a tool, preferably components used in cementing operations, and, especially, in one aspect of the invention, means to assist in sealing the end of the liner distant from said opposite end of the pipe.

The invention further relates to a novel liner-die assembly. In this aspect, the invention comprises the novel wellbore liner in which there is disposed the die-expansion assembly of the invention, as described, the assembly being disposed in said liner with the longitudinal axis of the means for transmitting fluid, or pipe, coincident with the axis of the liner and the fluid tight die member positioned in the remainder segment of the liner.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 illustrates schematically the prior art practice of telescoping liner sections.

FIG. 2 illustrates schematically a liner and liner assembly according to the invention.

FIGS. 3 and 4 illustrate sectional views of liner expansion tools according to the invention.

FIGS. 5 through 7 illustrate schematically the pipe expansion method or process of the invention.

DETAILED DESCRIPTION OF THE INVENTION

For a fuller understanding of the invention, reference is made to the drawing. Accordingly, in FIG. 1 there is shown a well string 1 extending to the earth surface 2 and to conductor pipe or casing 3. Conductor pipe 3 is positioned in the portion 4*a* of wellbore 4, while pipe 5 is in reduced diameter section 4*b* of the same wellbore. The wellbore forms segmented annulus 6 with pipes 3 and 5, the width of the annulus segments being the same or approximately the same. A further reduced diameter section 9 is illustrated. As indicated, standard cementing operations provide a cemented annulus which stabilizes the wellbore, but the effective diameter of the conducting passage is progressively and substantially reduced as the well is deepened.

FIG. 2 illustrates an important aspect of the invention. Accordingly, in FIG. 2 there is shown a liner-die assembly designated generally as 10. The assembly includes the liner component 11 which, as shown, comprises a liner head section 12 which includes a section of reduced external and internal diameter coupled to a main body portion or remainder segment 13. In a practical case, the external diameter of the section of reduced external and internal diameter may be reduced from that of the remainder segment on the order of two inches or so, with a corresponding decrease in the internal diameter of the reduced diameter section. As will be understood by those skilled in the art, a "liner" or "casing" will be composed of segments or sections assembled and coupled by suitable means, such as by threading. In the present invention, the section of reduced external and internal diameter 12 may be formed in one or composed of more than one section of liner, it being recognized that the remainder section or segment will normally comprise many sections (30 ft.) to the end or bottom end thereof. Head section 12, which comprises a deformable material, preferably is connected to the main segment of the liner 13 by appropriate threading of the two segments. Alternately, not shown, the head section and a portion of the remainder or main body segment may be of integral construction. An elastic or compressible sleeve (e.g., rubber) or sleeves 12*a* may be provided on head section 12 for stability and sealing. A preferred fluid tight die assembly, indicated generally as 14, and described more fully hereinafter, is provided. The preferred assembly 14 includes suitable mounting means or connecting means, such as a threaded connection 15, for connecting to a running string or other tool, and may be provided with threads or other suitable connecting means to

connect to other tools, e.g., cementing operation components, indicated generally at **16**, such as wiper plug launching apparatus, as described, for example, in U.S. Ser. No. 08/805,782, filed Feb. 25, 1997, by Gilbert Lavaure, Jason Jonas, and Bernard Piot, incorporated herein by reference. Liner segment **13** is provided with suitable partial sealing means **17**, such as a differential fill-up collar, at or near the end of the liner opposite the suspending or connecting means, to allow ingress of fluid into the liner during insertion thereof in the enlarged wellbore, seal the liner from ingress of fluid from the wellbore after its insertion, and prevent egress of fluid from the bore of segment **13** (as described more fully hereinafter). As will be evident to those skilled in the art, a portion of the liner containing the die assembly may suitably be lowered into a wellbore as a unit, to the purpose that, upon completion of the cementing and deforming technique described more fully hereinafter, a suitable cemented liner combination of genuine advantage is provided.

FIG. **3** illustrates the simplest form of the die member assembly. Accordingly, there is shown a die member **20** of suitable shape and composition, such as hardened steel, and adapted or sized and shaped to expand a liner section of reduced diameter. Other suitable die forming materials are well known, and the particular die member material utilized is a matter of choice. In the illustration, the die member **20** comprises enlarged sections of variable diameter and is of generally frustoconical shape provided with suitable beveling in the segment of the die member where shaping of the liner section will be initiated, although other deforming shapes of the die member may be provided. In each application of the invention, the die member will be shaped or designed to provide an at least substantially uniform expanded or deformed liner segment of circular or approximately circular periphery, the die structure being selected to provide a periphery of the deformed and expanded segment equal to or approximating (slightly larger or less than) the periphery of the remainder segment of the liner. As will be recognized by those skilled in the art, die structures are known, for example, which will deform the reduced diameter segment to provide an expanded internal periphery slightly larger than that of the die. This aspect of the invention is preferred, since there is the possibility of a virtual force fit of the expanded section in the casing or upper liner.

In this illustration, the die member **20** further comprises a fluid tight seal **21**, as previously described, such as a polymer cupseal, for sealing the die in a liner and allowing sufficient fluid pressure, as described hereinafter, to produce movement of the die member. The particular sealing material may be selected by those skilled in the art, a wide variety of sealing materials being suitable. For example, rubber or neoprene may also be utilized. The die member is provided with a bore or means **22** for transmitting a fluid in its center, and the bore terminates at both ends thereof with or in connecting means. Thus, threads are provided at **23** and **24** for connecting the die member to a running string or a tool, and suspending and/or positioning components, respectively.

A preferred embodiment of the die assembly is illustrated in greater detail in FIG. **4**. The die assembly shown comprises a pipe or generally tubular body **25** having threaded connecting means or segments **26** and **27** (box and pin) for connecting to a running string and suspending a tool or suitable cementing components in a liner, respectively. A die member **28** is provided on pipe **25** and is preferably of integral construction therewith, being of suitable shape and composition, as described with respect to FIG. **3**, and adapted or sized and shaped in a similar manner to expand a liner section such as liner section **12**. The connecting means, in whatever form employed, e.g., as also shown in FIG. **3**, thus enables the positioning or adjustment of the position of the die member in a liner by movement, for example, of a drillstring attached thereto. If not of integral construction, die member **28** may be mounted on pipe **25** by suitable mounting means (not shown). In a manner similar to the embodiment of FIG. **3**, the die member **28** comprises enlarged sections of variable diameter and is of generally frustoconical shape provided with suitable beveling in the segment of the die member where shaping of the liner section **12** will be initiated, although other deforming shapes of the die member may be provided. The die member **28** further comprises a fluid tight seal **29**, as previously described.

The procedure of the invention and operation of the liner **10** assembly and die assembly **14** are understood more fully by reference to schematic FIGS. **5** through **7**. Elements previously described with respect to FIGS. **1** through **4** are referred to by identical numbers. Accordingly, in FIG. **5** the liner assembly is provided in a wellbore **30**, such as an oil or gas well bore, and positioned in relation to cemented casing **31**, as shown. Wellbore **30** has a diameter greater than the external diameter of casing **31**, such wellbores being obtainable by use of a bi-center bit, under-reamer bit, or similar tool known to those skilled in the art. The external diameter of liner segment **13** is preferably slightly smaller than the internal diameter of casing **31**, being just sufficiently smaller to allow lowering thereof through casing **31**. The liner assembly is positioned in the enlarged wellbore, as shown, so that fluids, e.g., drilling mud or cement slurry, may be passed down the string **1** and via the pipe or bore **25** into the liner segment **13** or suitable tools or structure therein, described more fully hereinafter, out of the liner segment **13**, and into the wellbore annulus **32**, and through the annulus segment **33**, which is formed by the external wall of section **12** and the lower portion of casing **31**. Liner section **12** is formed, as mentioned, of a deformable liner material, such as a metal, e.g., steel or other alloy, which is suitable for liner duty. As used herein, the term "deformable" is understood in its common sense as indicating a capacity for shaping or expansion by suitable application of mechanical pressure. The fluid tight die assembly is positioned or disposed in the liner so that the longitudinal axes of the pipe and the liner are coincident. Pipe **25** may be of variable length and may or may not extend from liner **11**. As will be evident to those skilled in the art, the invention is particularly adapted to use of liners of decreased wall thickness.

As previously mentioned, liner segment **13** is provided with suitable structure **17**, at or near the end of the remainder segment of the liner, disposed from the die assembly, to allow ingress of fluid from the wellbore, such as a displacement fluid, during insertion of the liner, and sealing of the liner from ingress of cement slurry after cementing. In the usual case, a differential fill-up collar will be employed at or near the bottom of the liner to prevent wellbore fluids from entering the liner, and any suitable such collar or similar device may be employed. A variety of such devices are described in *Well Cementing*, edited by E. I. Nelson, Schlumberger Educational Services (1990), and the selection of a particular device is well within the ambit of those skilled in the art. Additionally, in order to seal the bottom of the liner after the cement has been placed in the wellbore annulus, as more fully described hereinafter, suitable sealing means, known to those skilled in the art, may be provided to

prevent egress of fluid from the liner. Preferably, the wiper plug system described in the aforementioned Ser. No. 08/805,782 may be employed, to the effect that a fluid tight seal is formed at the end of the liner distant from the assembly, or the bottom of the liner.

In the position shown in FIG. 5, the liner assembly is especially adapted to a cementing operation, and hanger elements are not required since the liner assembly may be supported by the string 1. More particularly, following standard cementing procedures, cement slurry may be pumped downhole through the string 1 and through liner 11 via pipe 25 in the die assembly, through flow distributor 16, which may be that of the aforementioned wiper plug launching system, and out the bottom of the liner through open sealing means 17. The cement slurry displaces drilling fluid and/or a suitable spacer fluid between the cement slurry and the drilling fluid in the wellbore annulus, the drilling fluid and/or spacer fluid passing from annulus 32 into annulus 33 in casing 31 without substantial impediment. The advantage of the reduced cross section of segment 12, which permits flow of fluids out of the wellbore, is demonstrated at this juncture. Without such feature, the ultimate goal of a wider cross section for production fluids cannot be achieved because of the requirement for removal of fluids from the borehole annulus. Sufficient cement slurry is employed to fill the annulus 32. The invention now provides for expansion of section 12 to provide for a larger diameter cross section corresponding to that of section 13.

As shown in FIG. 6, sealing means 17 (schematically shown) at the bottom of liner section 13 is sealed to the ingress and egress of fluid. In the normal case, a wiper plug, which is solid, is sent downhole, after sufficient cement slurry has been sent into annulus 32, to seal, with the differential fillup collar, the bottom of liner to egress of fluid. As mentioned, the technique of the aforementioned Ser. No. 08/805,782 is preferred. Fluid pressure is then applied to the bore of the liner segment 13 by pumping a fluid through the pipe 25 into the bore of liner 13. Any suitable wellbore fluid or liquid available may be used, e.g., a displacement fluid, a completion fluid, water, or sea water. The fluid is pumped at sufficient pressure, e.g., 3000 psig, through pipe 25 to provide upward movement of die member 28 if the member is freed for movement. To this end, the position of the die assembly (including die member 28) is adjusted or allowed to adjust upward by gradual upward movement of the running string 1. Adjustment of the drillstring length is made at a rate sufficient to move the die member upward or allow upward movement thereof, caused by the pressure on the die, at a controlled rate, in response to such continued sufficient application of fluid pressure, the continued application of sufficient pressure being indicated by change in drillstring weight. As continuing sufficient fluid pressure moves die member 28 upward, its movement causes the die member 28 to expand and shape the deformable liner section 12 so that the section diameter and radial cross section thereof equals or approximates the diameter and radial cross section of the lower section 13. Further application of fluid pressure in the bore of liner 11 with continued adjustment of the position of die member 28 will free the die 28 from the liner 11, as shown in FIG. 7. The result of the deformation operation is the provision of an upper segment 12 of the liner 11 which now corresponds in size to that of lower segment 13. The cement is then allowed to set, producing a stabilized wellbore with increased flow capability over conventional liner sequence technique.

While the invention has been described with reference to specific embodiments, it is understood that various modifications and embodiments will be suggested to those skilled in the art upon reading and understanding this disclosure. Accordingly, it is intended that all such modifications and embodiments be included within the invention and that the scope of the invention be limited only by the appended claims.

What is claimed is:

1. A method of cementing a wellbore comprising providing a casing in a wellbore and drilling a further segment of enlarged wellbore;

providing in the enlarged wellbore, through the casing, a liner of smaller external diameter comprising a minor section of further reduced external and internal diameter composed of a deformable liner material, and a remainder segment having an external diameter approximating the internal diameter of the casing, containing a movable fluid tight die member in the bore thereof at a location in the bore distant from the bottom end of said remainder segment, the liner further comprising means for transmitting a fluid to the bore of the remainder segment below the fluid tight die member, through the fluid tight die member, the section of reduced external and internal diameter being positioned in the lower portion of said casing in such manner, and the remainder segment of the liner below the lower portion of the casing in the enlarged wellbore, so that fluid may circulate without substantial impediment in the annuli formed by said liner and the enlarged wellbore and casing;

pumping a cement slurry down the casing and through the liner, and into the wellbore annulus in an amount sufficient to cement said wellbore annulus;

sealing the bottom of the remainder segment of the liner;

transmitting a fluid to and applying sufficient fluid pressure to the bore of the remainder segment of the liner below the fluid tight die member to move the die member up the liner and expand said minor section, and allowing said fluid tight die member to move up the wellbore to provide an external diameter of the minor section equal to or approximating that of the remainder segment of the liner;

and removing the fluid tight die member from the expanded minor section and allowing the cement to set.

2. A method of cementing a wellbore comprising

providing a first liner in a wellbore and drilling a further segment of enlarged wellbore;

providing in the enlarged wellbore, through the first liner, a second liner of smaller external diameter comprising a minor section of further reduced external and internal diameter composed of a deformable liner material, and a remainder segment having an external diameter approximating the internal diameter of the liner, containing a fluid tight die member in the bore thereof, at a location in the bore distant from the bottom end of said remainder segment, the liner further comprising means for transmitting a fluid to the bore of the remainder segment below the fluid tight die member, through the fluid tight die member, the section of reduced external and internal diameter being positioned in the lower portion of said first liner in such manner, and the remainder segment of the second liner below the lower portion of the first liner in the enlarged wellbore, so that fluid may circulate without substantial impediment in the annuli formed by said liner and the enlarged wellbore and first liner;

pumping a cement slurry down the first liner and through the second liner, and into the wellbore annulus in an amount sufficient to cement said wellbore annulus;

sealing the bottom of the remainder segment of the second liner;

transmitting a fluid to and applying sufficient fluid pressure to the bore of the remainder segment of the second liner below the fluid tight die member to move the die member up the liner and expand said minor section, and allowing said fluid tight die to move up the wellbore to provide an external diameter of the minor section equal to or approximating that of the remainder segment of the liner;

and removing the fluid tight die member from the expanded minor section and allowing the cement to set.

3. An improved wellbore liner for ameliorating subsequent casing diameter reduction, comprising a section of reduced external and internal diameter composed of a deformable liner material and a larger remainder segment of increased external and internal diameter, and a fluid tight die member disposed in the bore of the remainder segment, wherein the fluid tight die member comprises a means for transmitting a fluid therethrough, and comprising a means for sealing an end of said liner at a location removed from the fluid tight die member.

4. Apparatus comprising a die member adapted for expanding, at least substantially uniformly, the bore of a liner;

sealing means positioned on the periphery of said die member adapted to provide a fluid tight seal between the bore of a liner and said die member;

means for transmitting a fluid through the die member;

means for connecting the die member to a drillstring;

and means for suspending a tool from the die member.

5. Apparatus comprising a pipe, a die member adapted for expanding, at least substantially uniformly, the bore of a liner, on the periphery of said pipe, and sealing means positioned on the periphery of said die member adapted to provide a fluid tight seal between the bore of said liner and said die member.

6. The apparatus of claim 5 wherein the pipe is provided at one end thereof with means for connecting the pipe to a drillstring.

7. Apparatus comprising a pipe, a die member adapted for expanding, at least substantially uniformly, the bore of a liner, on the periphery of said pipe, and sealing means positioned on the periphery of said die member adapted to provide a fluid tight seal between the bore of said liner and said die member, and wherein said pipe is provided at one end thereof with a means for connecting the pipe and at the opposite end thereof, a means for suspending a tool.

8. A wellbore liner for ameliorating subsequent casing diameter reduction associated with subterranean drilling operations comprising

(a) a section of reduced external and internal diameter composed of a deformable liner material and a larger remainder segment of increased external and internal diameter;

(b) a fluid tight die assembly disposed in said liner, said assembly comprising a fluid tight die member including a sealing means on the periphery of a pipe, the assembly disposed in said liner with the longitudinal axis of the pipe coincident with the axis of the liner and the fluid tight die member positioned in the remainder segment of the liner.

9. A wellbore liner comprising a section of reduced external and internal diameter composed of a deformable liner material and a larger remainder segment of increased external and internal diameter, and at least one sleeve composed of a compressible material mounted on the periphery of the section of reduced external and internal diameter.

10. The liner of claim 9 in which the compressible material is rubber.

11. A method of cementing a wellbore comprising providing a casing in a wellbore and drilling a further segment of enlarged wellbore;

providing in the enlarged wellbore, through the casing, and connected to a drillstring, a liner of smaller external diameter comprising a minor section of further reduced external and internal diameter composed of a deformable liner material, and a remainder segment having an external diameter approximating the internal diameter of the casing, containing a movable fluid tight die member in the bore thereof at a location in the bore distant from the bottom end of said remainder segment, the liner further comprising means for transmitting a fluid to the bore of the remainder segment below the fluid tight die member, through the fluid tight die member, the section of reduced external and internal diameter being positioned in the lower portion of said casing in such manner, and the remainder segment of the liner below the lower portion of the casing in the enlarged wellbore, so that fluid may circulate without substantial impediment in the annuli formed by said liner and the enlarged wellbore and casing;

pumping a cement slurry down the casing and through the liner, and into the wellbore annulus in an amount sufficient to cement said wellbore annulus;

sealing the bottom of the remainder segment of the liner;

transmitting a fluid to and applying sufficient fluid pressure to the bore of the remainder segment of the liner below the fluid tight die member to move the die member up the liner and expand said minor section, and moving said fluid tight die member up the wellbore in response to continued sufficient fluid pressure by adjusting the position of the drillstring upward, to provide an external diameter of the minor section equal to or approximating that of the remainder segment of the liner;

and removing the fluid tight die member from the expanded minor section and allowing the cement to set.

12. The method of claim 11 wherein the well is a hydrocarbon well.

* * * * *

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Cook

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(45) **Date of Patent: Dec. 11, 2001**

(54) **ISOLATION OF SUBTERRANEAN ZONES**

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(22) Filed: **Nov. 15, 1999**

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(51) **Int. Cl.**[7] **E21B 43/14**

(52) **U.S. Cl.** **166/387**; 166/50; 166/117.6

(58) **Field of Search** 166/50, 313, 117.5, 166/117.6, 387, 66.6, 205

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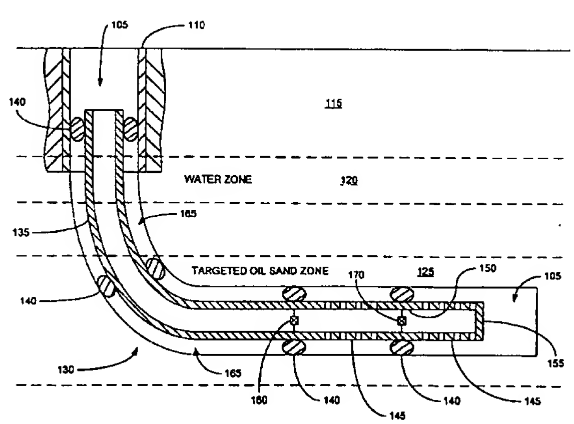
(57) **ABSTRACT**

One or more subterranean zones are isolated from one or more other subterranean zones using a combination of solid tubulars and slotted tubulars.

35 Claims, 1 Drawing Sheet



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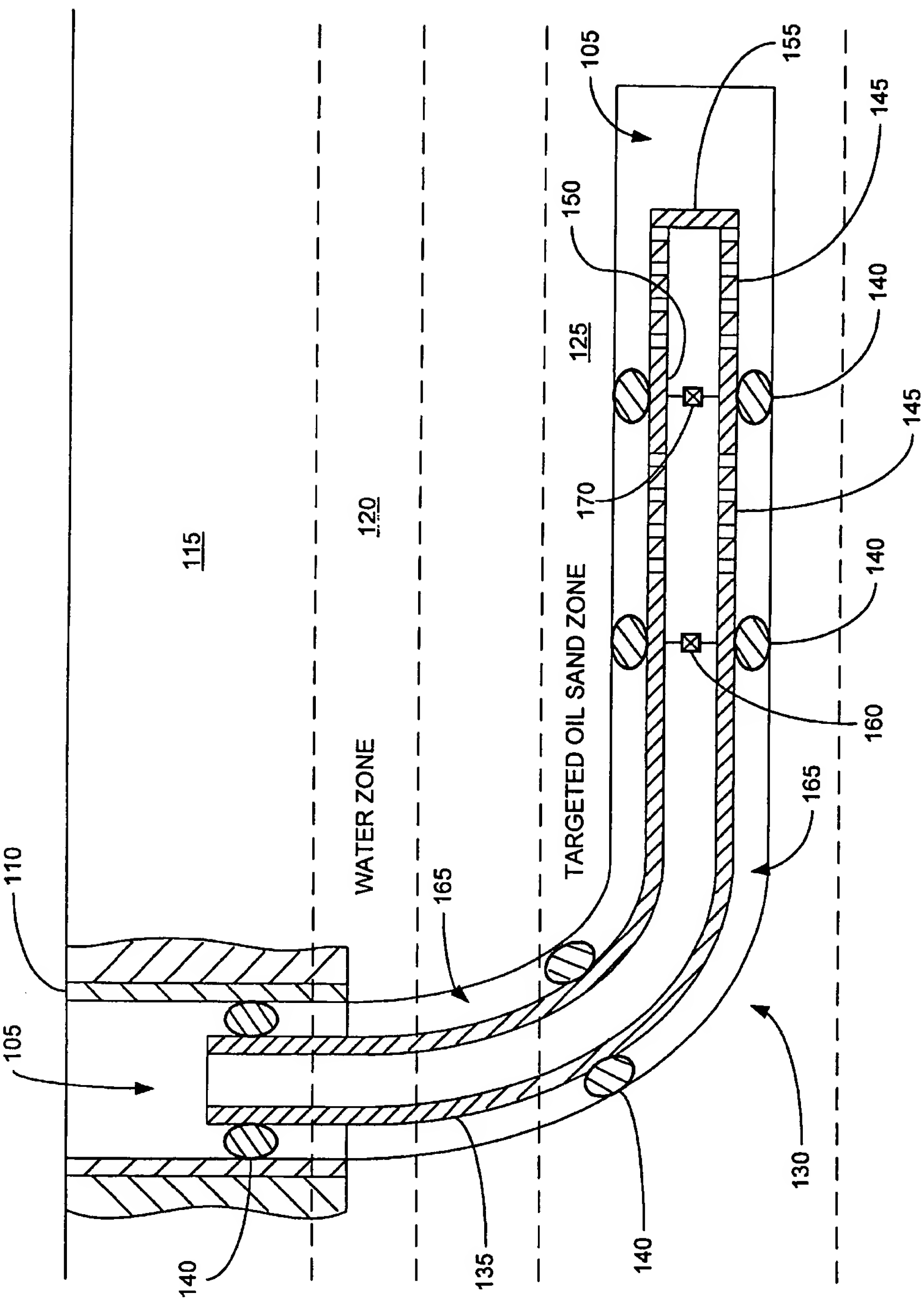

110
105
140
115
120
WATER ZONE
165
135
TARGETED OIL SAND ZONE
125
105
150
155
145
140
170
145
140
160
165
130
140

FIGURE 1

ISOLATION OF SUBTERRANEAN ZONES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the filing date of U.S. Provisional Patent Application Serial No. 60/108,558, filed on Nov. 16, 1998, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates generally to oil and gas exploration, and in particular to isolating certain subterranean zones to facilitate oil and gas exploration.

During oil exploration, a wellbore typically traverses a number of zones within a subterranean formation. Some of these subterranean zones will produce oil and gas, while others will not. Further, it is often necessary to isolate subterranean zones from one another in order to facilitate the exploration for and production of oil and gas. Existing methods for isolating subterranean production zones in order to facilitate the exploration for and production of oil and gas are complex and expensive.

The present invention is directed to overcoming one or more of the limitations of the existing processes for isolating subterranean zones during oil and gas exploration.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, an apparatus is provided that includes one or more solid tubular members, one or more slotted tubular members, and a shoe. The slotted tubular members are coupled to the solid tubular members. The shoe is coupled to the slotted tubular members. Each solid tubular member includes one or more external seals.

According to another aspect of the present invention, an apparatus is provided that includes one or more primary solid tubulars, n slotted tubulars, n−1 intermediate solid tubulars, and a shoe. Each primary solid tubular includes one or more external annular seals. The slotted tubulars are coupled to the primary solid tubulars. The intermediate solid tubulars are coupled to and interleaved among the slotted tubulars. Each intermediate solid tubular includes one or more external annular seals. The shoe is coupled to one of the slotted tubulars.

According to another aspect of the present invention, a method of isolating a first subterranean zone from a second subterranean zone in a wellbore is provided that includes positioning one or more primary solid tubulars, and one or more slotted tubulars within the wellbore. The primary solid tubulars traverse the first subterranean zone. The slotted tubulars traverse the second subterranean zone. The slotted tubulars and the primary solid tubulars are fluidicly coupled. The passage of fluids from the first subterranean zone to the second subterranean zone within the wellbore external to the solid and slotted tubulars is prevented.

According to another aspect of the present invention, a method of extracting materials from a producing subterranean zone in a wellbore, in which at least a portion of the wellbore includes a casing, is provided that includes positioning one or more primary solid tubulars and slotted tubulars within the wellbore. The primary solid tubulars are fluidicly coupled with the casing. The slotted tubulars traverse the producing subterranean zone. The producing subterranean zone is fluidicly isolated from at least one other subterranean zone within the wellbore. At least one of the slotted tubulars is fluidicly coupled with the producing subterranean zone.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary cross-sectional view illustrating the isolation of subterranean zones.

DETAILED DESCRIPTION OF THE ILLUSTRATION EMBODIMENTS

An apparatus and method for isolating one or more subterranean zones from one or more other subterranean zones is provided. The apparatus and method permits a producing zone to be isolated from a nonproducing zone using a combination of solid and slotted tubulars. In the production mode, the teachings of the present disclosure may be used in combination with conventional, well known, production completion equipment and methods using a series of packers, solid tubing, perforated tubing, and sliding sleeves, which will be inserted into the disclosed apparatus to permit the commingling and/or isolation of the subterranean zones from each other.

Referring to FIG. **1**, a wellbore **105** including a casing **110** are positioned in a subterranean formation **115**. The subterranean formation **115** includes a number of productive and non-productive zones, including a water zone **120** and a targeted oil sand zone **125**. During exploration of the subterranean formation **115**, the wellbore **105** may be extended in a well known manner to traverse the various productive and non-productive zones, including the water zone **120** and the targeted oil sand zone **125**.

In a preferred embodiment, in order to fluidicly isolate the water zone **120** from the targeted oil sand zone **125**, an apparatus **130** is provided that includes one or more sections of solid casing **135**, one or more external seals **140**, one or more sections of slotted casing **145**, one or more intermediate sections of solid casing **150**, and a solid shoe **155**.

The solid casing **135** may provide a fluid conduit that transmits fluids and other materials from one end of the solid casing **135** to the other end of the solid casing **135**. The solid casing **135** may comprise any number of conventional commercially available sections of solid tubular casing such as, for example, oilfield tubulars fabricated from chromium steel or fiberglass. In a preferred embodiment, the solid casing **135** comprises oilfield tubulars available from various foreign and domestic steel mills.

The solid casing **135** is preferably coupled to the casing **110**. The solid casing **135** may be coupled to the casing **110** using any number of conventional commercially available processes such as, for example, welding, slotted and expandable connectors, or expandable solid connectors. In a preferred embodiment, the solid casing **135** is coupled to the casing **110** by using expandable solid connectors. The solid casing **135** may comprise a plurality of such solid casing **135**.

The solid casing **135** is preferably coupled to one more of the slotted casings **145**. The solid casing **135** may be coupled to the slotted casing **145** using any number of conventional commercially available processes such as, for example, welding, or slotted and expandable connectors. In a preferred embodiment, the solid casing **135** is coupled to the slotted casing **145** by expandable solid connectors.

In a preferred embodiment, the casing **135** includes one more valve members **160** for controlling the flow of fluids and other materials within the interior region of the casing **135**. In an alternative embodiment, during the production

mode of operation, an internal tubular string with various arrangements of packers, perforated tubing, sliding sleeves, and valves may be employed within the apparatus to provide various options for commingling and isolating subterranean zones from each other while providing a fluid path to the surface.

In a particularly preferred embodiment, the casing **135** is placed into the wellbore **105** by expanding the casing **135** in the radial direction into intimate contact with the interior walls of the wellbore **105**. The casing **135** may be expanded in the radial direction using any number of conventional commercially available methods.

The seals **140** prevent the passage of fluids and other materials within the annular region **165** between the solid casings **135** and **150** and the wellbore **105**. The seals **140** may comprise any number of conventional commercially available sealing materials suitable for sealing a casing in a wellbore such as, for example, lead, rubber or epoxy. In a preferred embodiment, the seals **140** comprise Stratalok epoxy material available from Halliburton Energy Services. The slotted casing **145** permits fluids and other materials to pass into and out of the interior of the slotted casing **145** from and to the annular region **165**. In this manner, oil and gas may be produced from a producing subterranean zone within a subterranean formation. The slotted casing **145** may comprise any number of conventional commercially available sections of slotted tubular casing. In a preferred embodiment, the slotted casing **145** comprises expandable slotted tubular casing available from Petroline in Abeerdeen, Scotland. In a particularly preferred embodiment, the slotted casing **145** comprises expandable slotted sandscreen tubular casing available from Petroline in Abeerdeen, Scotland.

The slotted casing **145** is preferably coupled to one or more solid casing **135**. The slotted casing **145** may be coupled to the solid casing **135** using any number of conventional commercially available processes such as, for example, welding, or slotted or solid expandable connectors. In a preferred embodiment, the slotted casing **145** is coupled to the solid casing **135** by expandable solid connectors.

The slotted casing **145** is preferably coupled to one or more intermediate solid casings **150**. The slotted casing **145** may be coupled to the intermediate solid casing **150** using any number of conventional commercially available processes such as, for example, welding or expandable solid or slotted connectors. In a preferred embodiment, the slotted casing **145** is coupled to the intermediate solid casing **150** by expandable solid connectors.

The last slotted casing **145** is preferably coupled to the shoe **155**. The last slotted casing **145** may be coupled to the shoe **155** using any number of conventional commercially available processes such as, for example, welding or expandable solid or slotted connectors. In a preferred embodiment, the last slotted casing **145** is coupled to the shoe **155** by an expandable solid connector.

In an alternative embodiment, the shoe **155** is coupled directly to the last one of the intermediate solid casings **150**.

In a preferred embodiment, the slotted casings **145** are positioned within the wellbore **105** by expanding the slotted casings **145** in a radial direction into intimate contact with the interior walls of the wellbore **105**. The slotted casings **145** may be expanded in a radial direction using any number of conventional commercially available processes.

The intermediate solid casing **150** permits fluids and other materials to pass between adjacent slotted casings **145**. The intermediate solid casing **150** may comprise any number of conventional commercially available sections of solid tubular casing such as, for example, oilfield tubulars fabricated from chromium steel or fiberglass. In a preferred embodiment, the intermediate solid casing **150** comprises oilfield tubulars available from foreign and domestic steel mills.

The intermediate solid casing **150** is preferably coupled to one or more sections of the slotted casing **145**. The intermediate solid casing **150** may be coupled to the slotted casing **145** using any number of conventional commercially available processes such as, for example, welding, or solid or slotted expandable connectors. In a preferred embodiment, the intermediate solid casing **150** is coupled to the slotted casing **145** by expandable solid connectors. The intermediate solid casing **150** may comprise a plurality of such intermediate solid casing **150**.

In a preferred embodiment, each intermediate solid casing **150** includes one more valve members **170** for controlling the flow of fluids and other materials within the interior region of the intermediate casing **150**. In an alternative embodiment, as will be recognized by persons having ordinary skill in the art and the benefit of the present disclosure, during the production mode of operation, an internal tubular string with various arrangements of packers, perforated tubing, sliding sleeves, and valves may be employed within the apparatus to provide various options for commingling and isolating subterranean zones from each other while providing a fluid path to the surface.

In a particularly preferred embodiment, the intermediate casing **150** is placed into the wellbore **105** by expanding the intermediate casing **150** in the radial direction into intimate contact with the interior walls of the wellbore **105**. The intermediate casing **150** may be expanded in the radial direction using any number of conventional commercially available methods.

In an alternative embodiment, one or more of the intermediate solid casings **150** may be omitted. In an alternative preferred embodiment, one or more of the slotted casings **145** are provided with one or more seals **140**.

The shoe **155** provides a support member for the apparatus **130**. In this manner, various production and exploration tools may be supported by the show **150**. The shoe **150** may comprise any number of conventional commercially available shoes suitable for use in a wellbore such as, for example, cement filled shoe, or an aluminum or composite shoe. In a preferred embodiment, the shoe **150** comprises an aluminum shoe available from Halliburton. In a preferred embodiment, the shoe **155** is selected to provide sufficient strength in compression and tension to permit the use of high capacity production and exploration tools.

In a particularly preferred embodiment, the apparatus **130** includes a plurality of solid casings **135**, a plurality of seals **140**, a plurality of slotted casings **145**, a plurality of intermediate solid casings **150**, and a shoe **155**. More generally, the apparatus **130** may comprise one or more solid casings **135**, each with one or more valve members **160**, n slotted casings **145**, n−1 intermediate solid casings **150**, each with one or more valve members **170**, and a shoe **155**.

During operation of the apparatus **130**, oil and gas may be controllably produced from the targeted oil sand zone **125** using the slotted casings **145**. The oil and gas may then be transported to a surface location using the solid casing **135**. The use of intermediate solid casings **150** with valve members **170** permits isolated sections of the zone **125** to be selectively isolated for production. The seals **140** permit the zone **125** to be fluidicly isolated from the zone **120**. The seals **140** further permits isolated sections of the zone **125** to

be fluidicly isolated from each other. In this manner, the apparatus **130** permits unwanted and/or non-productive subterranean zones to be fluidicly isolated.

In an alternative embodiment, as will be recognized by persons having ordinary skill in the art and also having the benefit of the present disclosure, during the production mode of operation, an internal tubular string with various arrangements of packers, perforated tubing, sliding sleeves, and valves may be employed within the apparatus to provide various options for commingling and isolating subterranean zones from each other while providing a fluid path to the surface.

An apparatus has been described that includes one or more solid tubular members, one or more slotted tubular members, and a shoe. Each solid tubular member includes one or more external seals. The slotted tubular members are coupled to the solid tubular members. The shoe is coupled to one of the slotted tubular members. In a preferred embodiment, the apparatus further includes one or more intermediate solid tubular members coupled to and interleaved among the slotted tubular members. Each intermediate solid tubular member preferably includes one or more external seals. In a preferred embodiment, one or more of the solid tubular members include one or more valve members. In a preferred embodiment, one or more of the intermediate solid tubular members include one or more valve members.

An apparatus has been described that includes one or more primary solid tubulars, n slotted tubulars, n−1 intermediate solid tubulars, and a shoe. Each primary solid tubular includes one or more external annular seals. The slotted tubulars are coupled to the primary solid tubulars. The intermediate solid tubulars are coupled to and interleaved among the slotted tubulars. Each intermediate solid tubular includes one or more external annular seals. The shoe is coupled to one of the slotted tubulars.

A method of isolating a first subterranean zone from a second subterranean zone in a wellbore has been described that includes positioning one or more primary solid tubulars and one or more slotted tubulars within the wellbore. The primary solid tubulars traverse the first subterranean zone and the slotted tubulars traverse the second subterranean zone. The slotted tubulars and the solid tubulars are fluidicly coupled. The passage of fluids from the first subterranean zone to the second subterranean zone within the wellbore external to the solid and slotted tubulars is prevented.

A method of extracting materials from a producing subterranean zone in a wellbore, at least a portion of the wellbore including a casing, has been described that includes positioning one or more primary solid tubulars and one or more slotted tubulars within the wellbore. The primary solid tubulars are fluidicly coupled with the casing. The slotted tubulars traverse the producing subterranean zone. The producing subterranean zone is fluidicly isolated from at least one other subterranean zone within the wellbore. At least one of the slotted tubulars is fluidicly coupled with the producing subterranean zone. In a preferred embodiment, the method further includes controllably fluidicly decoupling at least one of the slotted tubulars from at least one other of the slotted tubulars.

Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

What is claimed is:

1. An apparatus, comprising:

one or more solid tubular members, each solid tubular member including one or more external seals;

one or more slotted tubular members coupled to the solid tubular members; and

a shoe coupled to one of the slotted tubular members.

2. The apparatus of claim 1, further comprising;

one or more intermediate solid tubular members coupled to and interleaved among the slotted tubular members, each intermediate solid tubular member including one or more external seals.

3. The apparatus of claim 2, wherein one or more of the intermediate solid tubular members include one or more valve members.

4. The apparatus of claim 1, further comprising one or more valve members for controlling the flow of fluidic materials between the tubular members.

5. The apparatus of claim 1, further comprising: a plurality of slotted tubular members coupled to the solid tubular member, each

slotted tubular member consisting of:

a tubular member defining a longitudinal passage and one or more radial passages fluidicly coupled to the longitudinal passage.

6. An apparatus, comprising:

one or more primary solid tubulars, each primary solid tubular including one or more external annular seals;

n slotted tubulars coupled to the primary solid tubulars;

n−1 intermediate solid tubulars coupled to and interleaved among the slotted tubulars, each intermediate solid tubular including one or more external annular seals; and

a shoe coupled to one of the slotted tubulars.

7. The apparatus of claim 6, wherein n is greater than or equal to 2.

8. The apparatus of claims 6, wherein n is greater than or equal to 2; and wherein each slotted tubular member consists of:

a tubular member defining a longitudinal passage and one or more radial passages fluidicly coupled to the longitudinal passage.

9. A method of isolating a first subterranean zone from a second subterranean zone in a wellbore, comprising:

positioning one or more primary solid tubulars within the wellbore, the primary solid tubulars traversing the first subterranean zone;

positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the second subterranean zone;

fluidicly coupling the slotted tubulars and the solid tubulars; and

preventing the passage of fluids from the first subterranean zone to the second subterranean zone within the wellbore external to the solid and slotted tubulars.

10. The method of claim 9, further comprising:

positioning a plurality of slotted tubulars within the wellbore, each slotted tubular consisting of:

a tubular member defining a longitudinal passage and one or more radial passages fluidicly coupled to the longitudinal passage.

11. A method of extracting materials from a producing subterranean zone in a wellbore, at least a portion of the wellbore including a casing, comprising;

positioning one or more primary solid tubulars within the wellbore;

fluidicly coupling the primary solid tubulars with the casing;

positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the producing subterranean zone;

fluidicly coupling the slotted tubulars with the solid tubulars;

fluidicly isolating the producing subterranean zone from at least one other subterranean zone within the wellbore; and

fluidicly coupling at least one of the slotted tubulars with the producing subterranean zone.

12. The method of claim **11**, further comprising:

controllably fluidicly decoupling at least one of the slotted tubulars from at least one other of the slotted tubulars.

13. The method of claim **11**, further comprising:

positioning a plurality of slotted tubulars within the wellbore, each slotted tubular consisting of:

a tubular member defining a longitudinal passage and one or more radial passages fluidicly coupled to the longitudinal passage.

14. An apparatus, comprising:

a subterranean formation including a wellbore;

one or more solid tubular members positioned within the wellbore, each solid tubular member including one or more external seals;

one or more slotted tubular members positioned within the wellbore coupled to the solid tubular members; and

a shoe positioned within the wellbore coupled to one of the slotted tubular members;

wherein at least one of the solid tubular members and the slotted tubular members are formed by a radial expansion process performed within the wellbore.

15. The apparatus of claim **14**, further comprising;

one or more intermediate solid tubular members positioned within the wellbore coupled to and interleaved among the slotted tubular members, each intermediate solid tubular member including one or more external seals;

wherein at least one of the solid tubular members, the slotted tubular members, and the intermediate solid tubular members are formed by a radial expansion process performed within the wellbore.

16. The apparatus of claim **15**, wherein one or more of the intermediate solid tubular members include one or more valve members for controlling the flow of fluids between the solid tubular members and the slotted tubular members.

17. The apparatus of claim **14**, further comprising one or more valve members for controlling the flow of fluids between the solid tubular members and the slotted tubular members.

18. An apparatus, comprising:

a subterranean formation including a wellbore;

one or more primary solid tubulars positioned within the wellbore, each primary solid tubular including one or more external annular seals;

n slotted tubulars positioned within the wellbore coupled to the primary solid tubulars;

n−1 intermediate solid tubulars positioned within the wellbore coupled to and interleaved among the slotted tubulars, each intermediate solid tubular including one or more external annular seals; and

a shoe coupled to one of the slotted tubulars;

wherein at least one of the primary solid tubulars, the slotted tubulars, and the intermediate solid tubulars are formed by a radial expansion process performed within the wellbore.

19. The apparatus of claim **18**, wherein n is greater than or equal to 2.

20. A method of isolating a first subterranean zone from a second subterranean zone in a wellbore, comprising:

positioning one or more primary solid tubulars within the wellbore, the primary solid tubulars traversing the first subterranean zone;

positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the second subterranean zone;

radially expanding at least one of the primary and slotted tubulars within the wellbore;

fluidicly coupling the slotted tubulars and the solid tubulars; and

preventing the passage of fluids from the first subterranean zone to the second subterranean zone within the wellbore external to the solid and slotted tubulars.

21. A method of extracting materials from a producing subterranean zone in a wellbore, at least a portion of the wellbore including a casing, comprising;

positioning one or more primary solid tubulars within the wellbore;

positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the producing subterranean zone;

radially expanding at least one of the primary solid tubulars and the slotted tubulars within the wellbore;

fluidicly coupling the primary solid tubulars with the casing;

fluidicly coupling the slotted tubulars with the solid tubulars;

fluidicly isolating the producing subterranean zone from at least one other subterranean zone within the wellbore; and

fluidicly coupling at least one of the slotted tubulars with the producing subterranean zone.

22. The method of claim **21**, further comprising:

controllably fluidicly decoupling at least one of the slotted tubulars from at least one other of the slotted tubulars.

23. An apparatus, comprising:

a subterranean formation including a wellbore;

n solid tubular members positioned within the wellbore, each solid tubular member including one or more external seals;

n−1 slotted tubular members positioned within the wellbore coupled to and interleaved among the solid tubular members; and

a shoe positioned within the wellbore coupled to one of the slotted tubular members.

24. The apparatus of claim **23**, further comprising one or more valve members for controlling the flow of fluids between the solid tubular members and the slotted tubular members.

25. The apparatus of claim **23**, wherein one or more of the solid tubular members include one or more valve members for controlling the flow of fluids between the solid tubular members and the slotted tubular members.

26. The apparatus of claim **23**, wherein n is greater than or equal to 3.

27. The apparatus of claim 23, wherein n is greater than or equal to 3; and wherein each slotted tubular member consists of:

a tubular member defining a longitudinal passage and one or more radial passages fluidicly coupled to the longitudinal passage.

28. A system for isolating a first subterranean zone from a second subterranean zone in a wellbore, comprising:

means for positioning one or more primary solid tubulars within the wellbore, the primary solid tubulars traversing the first subterranean zone;

means for positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the second subterranean zone;

means for fluidicly coupling the slotted tubulars and the solid tubulars; and

means for preventing the passage of fluids from the first subterranean zone to the second subterranean zone within the wellbore external to the solid and slotted tubulars.

29. The system of claim 28, further comprising means for positioning a plurality of slotted tubulars within the wellbore; wherein each slotted tubular consists of:

a tubular member defining a longitudinal passage and one or more radial passages fluidicly coupled to the longitudinal passage.

30. A system for extracting materials from a producing subterranean zone in a wellbore, at least a portion of the wellbore including a casing, comprising;

means for positioning one or more primary solid tubulars within the wellbore;

means for fluidicly coupling the primary solid tubulars with the casing;

means for positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the producing subterranean zone;

means for fluidicly coupling the slotted tubulars with the solid tubulars;

means for fluidicly isolating the producing subterranean zone from at least one other subterranean zone within the wellbore; and

means for fluidicly coupling at least one of the slotted tubulars with the producing subterranean zone.

31. The system of claim 30, further comprising: means for controllably fluidicly decoupling at least one of the slotted tubulars from at least one other of the slotted tubulars.

32. The system of claim 30, further comprising means for positioning a plurality of slotted tubulars within the wellbore; wherein each slotted tubular consists of:

a tubular member defining a longitudinal passage and one or more radial passages fluidicly coupled to the longitudinal passage.

33. A system for isolating a first subterranean zone from a second subterranean zone in a wellbore, comprising:

means for positioning one or more primary solid tubulars within the wellbore, the primary solid tubulars traversing the first subterranean zone;

means for positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the second subterranean zone;

means for radially expanding at least one of the primary and slotted tubulars within the wellbore;

means for fluidicly coupling the slotted tubulars and the solid tubulars; and

means for preventing the passage of fluids from the first subterranean zone to the second subterranean zone within the wellbore external to the solid and slotted tubulars.

34. A system for extracting materials from a producing subterranean zone in a wellbore, at least a portion of the wellbore including a casing, comprising;

means for positioning one or more primary solid tubulars within the wellbore;

means for positioning one or more slotted tubulars within the wellbore, the slotted tubulars traversing the producing subterranean zone;

means for radially expanding at least one of the primary solid tubulars and the slotted tubulars within the wellbore;

means for fluidicly coupling the primary solid tubulars with the casing;

means for fluidicly coupling the slotted tubulars with the solid tubulars;

means for fluidicly isolating the producing subterranean zone from at least one other subterranean zone within the wellbore; and

means for fluidicly coupling at least one of the slotted tubulars with the producing subterranean zone.

35. The system of claim 34, further comprising:

means for controllably fluidicly decoupling at least one of the slotted tubulars from at least one other of the slotted tubulars.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,328,113 B1
DATED : December 11, 2001
INVENTOR(S) : Robert Lance Cook

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
Please add the following under U.S. PATENT DOCUMENTS,

-- 4,069,573 01/1978 Rogers, Jr., et al. .... 29/421 R --

Column 2,
Line 10, please replace "ILLUSTRATION" with -- ILLUSTRATIVE --

Column 4,
Line 42, please replace "show 150" with -- shoe 155 --
Line 42, please replace "shoe 150" with -- shoe 155 --
Line 46, please replace "shoe 150" with -- shoe 155 --

Column 6,
Line 67, please replace ";" with -- : --

Signed and Sealed this

Second Day of July, 2002

Attest:

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

Attesting Officer

United States Patent [19]

Hoes et al.

[11] **Patent Number: 5,026,074**

[45] **Date of Patent: Jun. 25, 1991**

[54] **ANNULAR METAL-TO-METAL SEAL**

[75] Inventors: **Larry M. Hoes**, Spring; **Joseph H. Hynes**, Houston, both of Tex.

[73] Assignee: **Cooper Industries, Inc.**, Houston, Tex.

[21] Appl. No.: **587,632**

[22] Filed: **Sep. 20, 1990**

Related U.S. Application Data

[63] Continuation of Ser. No. 374,475, Jun. 30, 1989, abandoned.

[51] **Int. Cl.**[5] **F16J 15/48; E21B 33/03**

[52] **U.S. Cl.** **277/27**; 166/115; 166/191; 277/198; 277/236; 285/96; 285/139

[58] **Field of Search** 277/27, 116.6, 236, 277/116.2, 116.4, 118, 125, 198, 199, 205; 285/96, 133.1, 140, 106, 110–111, 133.2, 329, 351–352; 166/208, 182, 382, 115, 206, 387, 195, 120, 202, 184, 186, 191, 196

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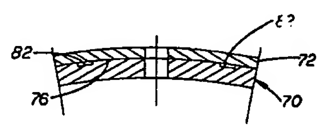
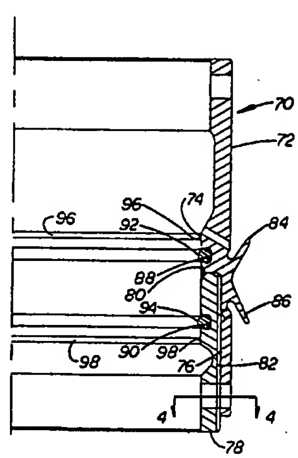
Primary Examiner—William A. Cuchlinski, Jr.
Assistant Examiner—Scott Cummings

[57] **ABSTRACT**

The improved annular seal of the present invention provides a seal across an annular space between facing cylindrical surfaces and includes an outer annular ring, inner annular ring, the gap between the outer annular ring and the inner annular ring being suitably sealed at one end thereof so that the open end is open to admit pressure which is to be sealed between the two rings, an outer sealing element on the exterior of said outer annular ring, and an inner sealing element on the interior of the inner annular ring so that pressure exerted between the annular rings urges them apart and their sealing elements against the surfaces of the annular space. In another form of the invention three annular rings are provided with one end of the inner and outer rings being sealing to the end of the intermediate ring and with sealing elements on the exterior of the outer ring and on the interior of the inner ring so that the sealing elements are urged into sealing engagement with the surfaces of the annular space. Another form of the invention includes annular rings which vary in thickness from one end to the other so that they may have greater or less flexibility as needed to provide a response to the pressure responsive movements of the inner and outer members.

6 Claims, 4 Drawing Sheets





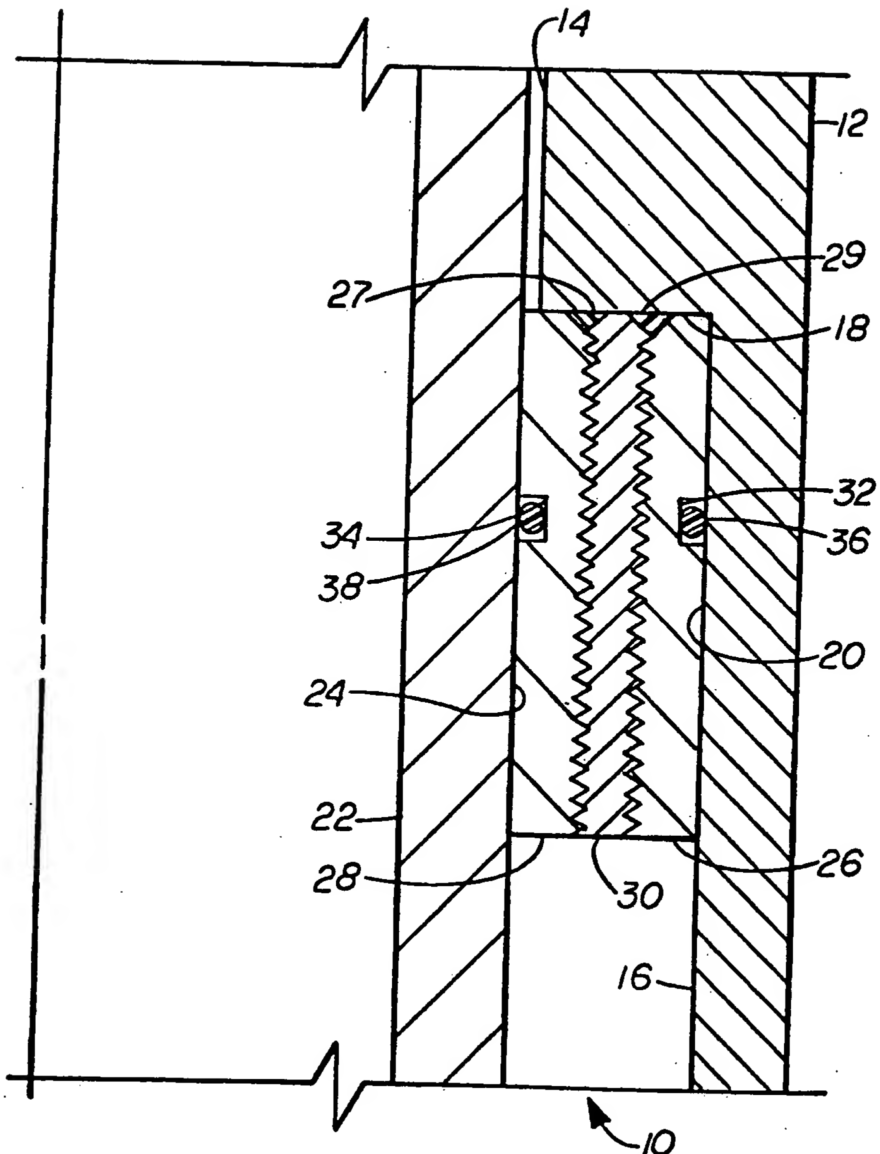


FIG. 1

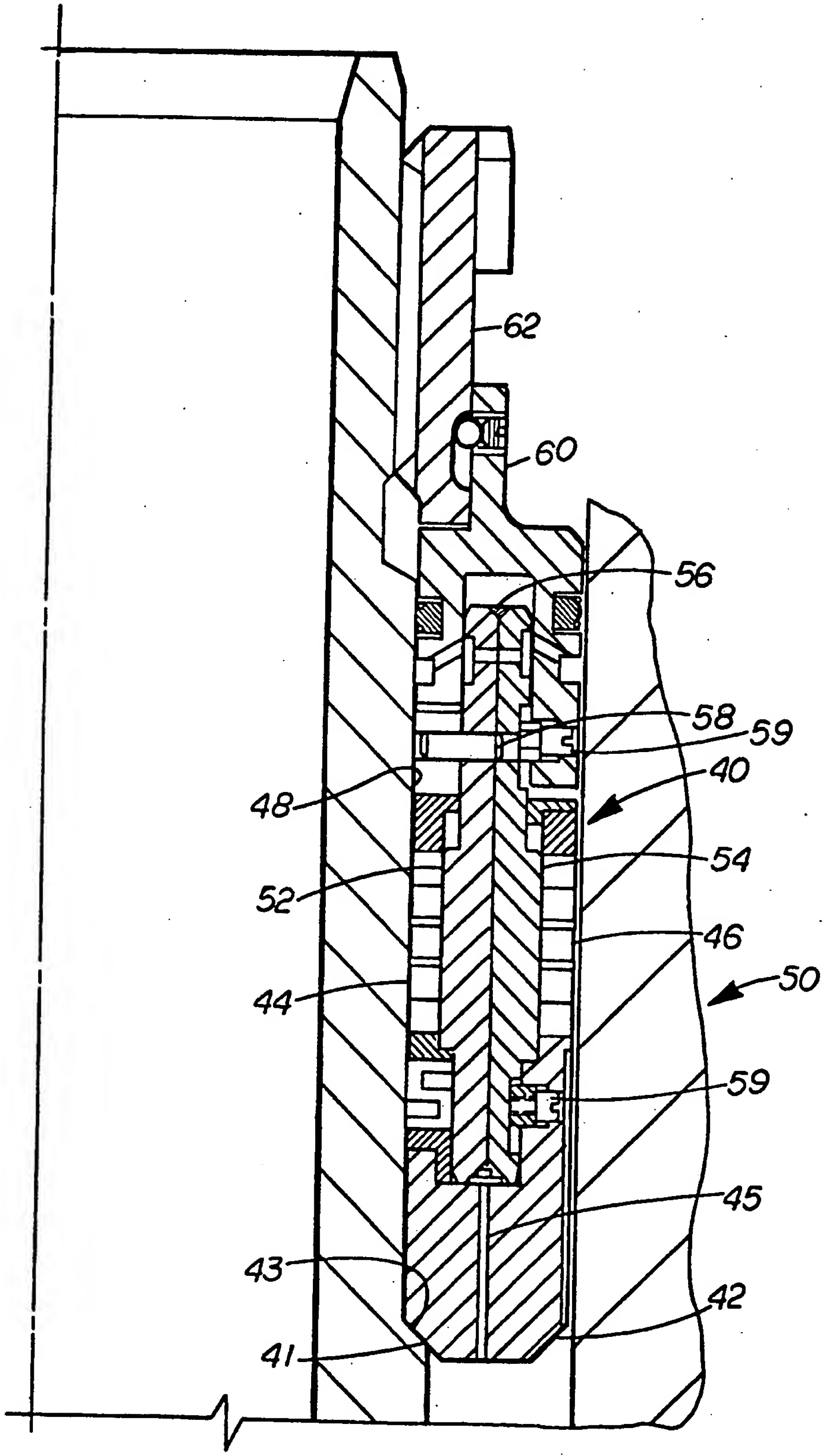


FIG. 2

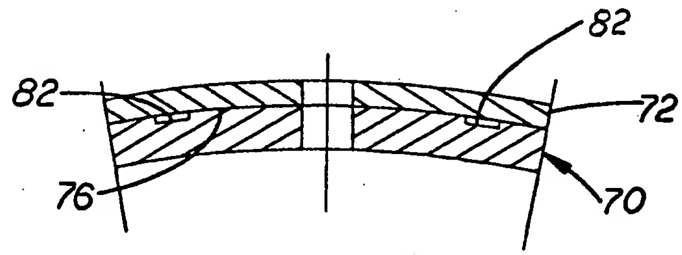


FIG.4

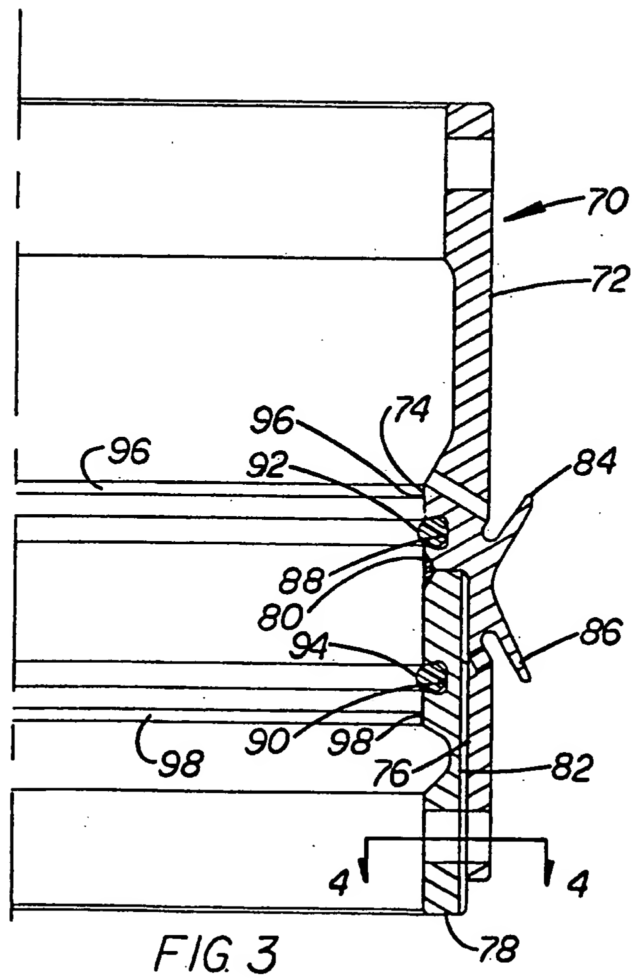


FIG. 3

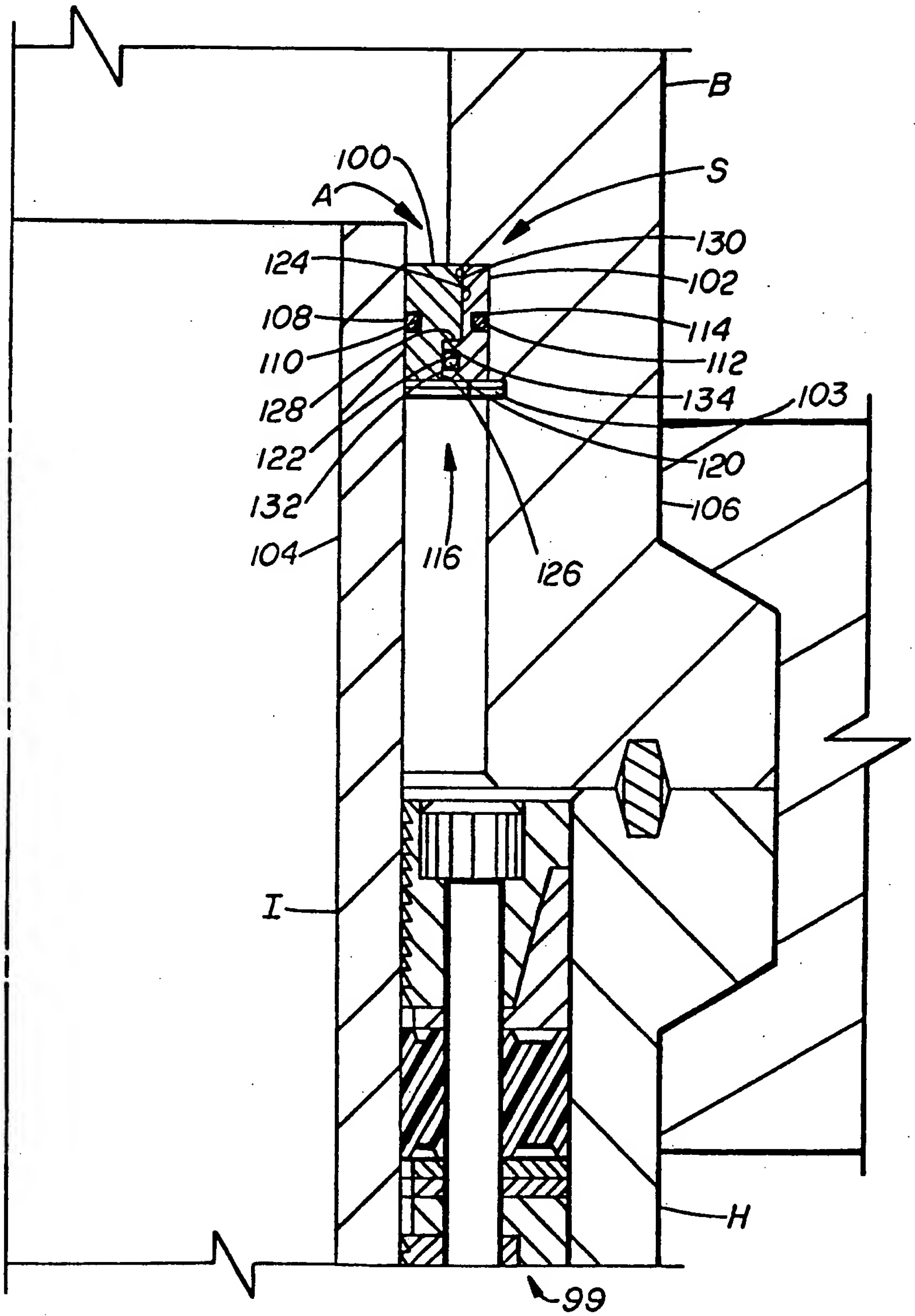

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FIG. 5

ANNULAR METAL-TO-METAL SEAL

This is a continuation of application Ser. No. 07/374,475 filed on June 30, 1989, abandoned.

BACKGROUND

The present invention relates to an improved annular seal which can be used to seal across the annular space between well members. Difficulty has been encountered in the past with annular seals since manufacturing tolerances and deflection of components due to hoop strain creates an extrusion gap and adversely affects the ability to seal, the seal life and for elastomers causes extrusion problems.

Efforts have been made in prior seal assemblies to provide a structure in which the pressure to which the seal is exposed is utilized to cause a lip to move in the direction to provide a sealing engagement with a cylindrical surface against which the seal is to be provided.

The H. W. Millmine U.S. Pat. No. 2,007,501 discloses a packing for a pump rod which is rubber or similar material and includes an outer lip and an inner lip with a compression space between the lips. The fluid being pumped is received within the compression space and exerts a pressure against both lips to hold them in sealing engagement with the surfaces against which they are to seal. A plurality of channels through the packing connect the compression space with a recess on the interior of the packing to provide cooling for the reciprocating rod which moves within the packing. A filter is provided at the intersection of the duct and the compression space to prevent the entry of sand and sediment into the rod cooling recess.

The S. D. Gullion U.S. Pat. No. 4,742,874 discloses a subsea wellhead seal assembly for sealing between the interior of a wellhead housing and the exterior of a hanger. The seal assembly includes a U-shaped metal seal ring with a pair of interengaged annular wedging members which are forced into the interior of the U-shaped metal seal ring to cause its inner and outer legs to be spread apart into sealing engagement with the walls on the interior of the housing and the exterior of the hanger.

The T. G. Cassity U.S. Pat. No. 4,771,828 discloses a wellhead seal which includes an annular sealing member for sealing across the annular space between two wellhead members. The annular sealing member includes a plurality of inner and outer lips which are tapered in a direction toward the surface against which they are to seal and toward the pressure to which they may be exposed. The sealing surfaces of the wellhead members are prepared to provide an undercut on the sealing surfaces so that the pressure to which the seal is exposed can enter the undercut space and urge the undercut portion of the sealing surface in the direction toward the annular sealing member. In this manner the pressure being sealed urges both the seal lips on the annular sealing member and the undercut sealing surface portions toward each other to provide a positive seal.

SUMMARY

The present invention relates to an improved annular seal for sealing across an annular space between facing cylindrical surfaces and includes an outer annular ring, inner annular ring, the gap between the outer annular ring and the inner annular ring being suitably sealed at one end thereof so that the open end is open to pressure which is to be sealed, an outer sealing element on the exterior of said outer annular ring, and an inner sealing element on the interior of said inner annular ring so that pressure exerted between the annular rings urges them apart and their sealing elements against the surfaces of the annular space. In another form of the invention three annular rings are provided with one end of the inner and outer rings being sealed to the end of the intermediate ring and with sealing elements on the exterior of the outer ring and on the interior of the inner ring so that the sealing elements are urged into sealing engagement with the surfaces of the annular space.

An object of the present invention is to provide an improved annular pressure seal having a longer active seal life.

Another object is to provide an improved annular pressure seal in which changes in the annular space due to deflections of the well members by the pressure being sealed does not alter the effectiveness of the seal.

A further object is to provide an improved annular pressure seal in which the pressure is utilized to allow the seal to accommodate changes in the annular space across which it is to seal which may be caused by manufacturing tolerances or may be a result of deflections of components caused by the pressure to which the annular space is exposed.

Still another object is to provide an improved annular pressure seal in which a pressure responsive element is provided between inner and outer seals to ensure the maintenance of the sealing engagement of the seals with the surfaces against which they are to seal.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects are hereinafter set forth, described and explained with reference to the drawings wherein:

FIG. 1 is a partial sectional view of the improved seal of the present invention positioned between well members with facing cylindrical surfaces between which the seal is provided.

FIG. 2 is another partial sectional view of a modified form of the improved seal of the present invention.

FIG. 3 is another partial sectional view of another modified form of the improved seal of the present invention which forms the annulus seal in a wellhead.

FIG. 4 is a partial transverse sectional view of the seal taken along line 4—4 in FIG. 3.

FIG. 5 is a partial sectional view of a modified form of seal of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 improved seal 10 of the present invention is illustrated within first tubular member 12 having upper bore 14 and counterbore 16 with shoulder 18 therebetween. The surface 20 of counterbore 16 is one of the sealing surfaces against which seal 10 is to seal. Second tubular member 22 has outer sealing surface 24 which is the other of the sealing surfaces against which seal 10 is to seal. In this manner seal 10 provides an annulus seal for sealing between members 12 and 22.

Seal 10 includes outer ring 26, inner ring 28 and intermediate ring 30. As shown, rings 26, 28 and 30 are threadedly engaged with suitable threading and having welding securing and sealing the upper end of rings 26 and 30 and of rings 28 and 30. The welding is at the end of rings 26, 28 and 30 opposite to the pressure end, i.e.,

the pressure is exerted on seal 10 from below and the non welded ends of the ring are herein termed the pressure end. The welded ends of rings 26, 28 and 30 are positioned against shoulder 18 as shown. Groove 32 in the exterior of outer ring 26 is provided a substantial distance from the welded end of rings 26 and 30 and groove 34 in the interior of inner ring 28 is provided a substantial distance from the welded end of rings 28 and 30. Suitable sealing means is provided within grooves 32 and 34, such as O rings 36 and 38, for sealing against the facing sealing surfaces 20 and 24.

The threaded engagement between ring 26 and ring 30 and between ring 30 and ring 28 is such that the pressure fluid which is exerted on seal from below enters between the rings and urges outer ring outwardly to assist in the sealing of O ring 36 against sealing surface 20 and urges inner ring 28 inwardly to assist in the sealing of O ring 38 against sealing surface 24.

The pressure within the threaded surfaces between the rings and above the seals 36 and 38 creates the force necessary to urge the inner and outer rings 26 and 28 toward their respective sealing surface so that the pressure exerted on the inner and outer tubular members 12 and 22 which may create an extrusion gap between the rings and the sealing surfaces does not occur because of the compensating pressure responsive movement of the rings 26 and 28.

Seal 10 as shown in FIG. 1 and described above is a simplified seal to illustrate the novel features of the present invention. Other forms of the invention are shown in the drawings but show additional details of the seals.

In the form of the present invention shown in FIG. 2, an improved annulus seal 40 is shown which includes lower body 42 having shoulder 41 which lands on seat 43, a plurality of bores 45 extending therethrough to transmit pressure from a position below body 42 to a position above body 42 which is between inner seal stack 44 and outer seal stack 46. Since body 42 is annular in shape, inner seal stack 44 includes a stack of sealing elements, anti-extrusion rings and other back-up elements which provide a suitable seal against the exterior of the inner member 48 and outer seal stack 46 includes a stack of sealing elements, anti-extrusion rings and other back-up elements which provide a suitable seal against the interior of outer member 50. Positioned within stacks 44 and 46 are inner ring 52 and outer ring 54. Rings 52 and 54 are secured and sealed together at their upper ends by weld 56. With pressure exerted on seal 40 from below, this pressure is exerted between rings 52 and 54 to cause them to be wedged apart to assist in the sealing forces exerted by stacks 44 and 46 in their sealing function. Suitable means 58 is provided to secure rings 52 and 54 in the desired position within stacks 44 and 46 and means 59 secures rings 52 and 54 to body 42 and cap ring 60. Cap ring 60 is secured to the upper ends of rings 52 and 54 and cap ring 60 is supported on sleeve 62, as shown, for lowering seal 40 into position between members 48 and 50.

Seal 70 shown in FIGS. 3 and 4 is a seal for use as an annulus seal for sealing across the annulus between the exterior of a hanger and the interior of a housing in which the hanger is landed. In sealing an annulus between a housing and a hanger landed therein, two sources of pressure can be encountered. If there is a fault in the cementing of the casing some pressure fluid may move upward in the space around the casing and enter the annulus within the housing to exert a pressure within the housing from a position below the annulus seal. This pressure is exerted to urge the housing outward and to urge the hanger inwardly. There would be no balancing or equalizing pressure within the hanger. In the other case, a pressure pocket could be encountered while drilling through the hanger and a pressure kick would be exerted through the interior of the hanger. To control such pressure kick, the blowout preventers above the hanger would be closed and the pressure would be exerted within the hanger and within the annulus above the seal. This pressure causes the housing to be urged outwardly and since there is no balancing or equalizing pressure around the major portion of the exterior of the hanger, there is an appreciable net force urging the hanger outward. The seal 70 is an improved seal structure which will maintain a sealing engagement across the annulus under either pressure condition described above.

Seal 70 includes tubular body 72 having central bore 74 and counterbore 76 extending therein from one end and body ring 78 which is positioned within counterbore 76 and is secured therein by welding 80. Grooves 82 in the exterior of body ring 78 provide communication for pressure fluids to enter between body ring 78 and counterbore 76 of body 72. Body 72 is configured on its exterior surface to provide annular seal lips 84 and 86 which are both tapered in a radially outward direction with upper seal lip 84 being directed upwardly and lower seal lip 86 being directed downwardly. Annular seal lips 84 and 86 are designed to seal against the interior of a housing bore. Groove 88 is provided in the interior of body 72 and groove 90 which is similar to groove 88 is provided in the interior of body ring 78. Elastomeric seals 92 and 94 are positioned in grooves 88 and 90 to seal against the exterior of a hanger which forms the interior of the annulus across which seal 70 is to seal.

Seal 70 includes the two main components, i.e., body 72 and body ring 78. It is preferred that body ring 78 be of a high strength metal and body 72 be of a soft material such as mild steel. With this configuration and with the materials suggested body ring 78 being of a high strength material maximizes the amount of stored energy from an interference fit of the interior of body ring 78 with respect to the inner sealing surface of the annulus. Also, the material of body 72 maximizes the ability of the seal lips to seal against scratches and other imperfections in the inner surface of the outer member of the annulus being sealed. The seal 70 also utilizes the pressure in the annulus in which it is positioned to urge body ring 78 inward and the lower portion of body 72 outward to assist in both the internal and external sealing of seal 70. It should be noted that the inner surface 96 upward of groove 88 is slightly smaller in diameter than bore 74 to provide an interference fit when seal 70 is installed around a hanger and similarly surface 98 which is at the other end of the inner surface or body ring 78 has a similar smaller diameter to provide an interference fit with the exterior of the surface against which seal 70 is to seal. With such sealing surfaces as surfaces 96 and 98 it is possible to eliminate the use of the elastomeric seals 92 and 94. Since such seals can be added immediately before the lowering of seal 70 into a well bore to seal around a hanger landed within an annulus, seal 70 can be provided without seals 92 and 94 and they can be added if desired immediately prior to their use.

It is suggested that by varying the relative thickness of body 72 around counterbore 76 and the thickness of

body ring 78, the respective movements of each can be adjusted so that they readily move with the movement of the hanger and the housing responsive to the pressure experienced in the annulus from below.

When the improved seal 70 is in position and subjected to pressure from below in the housing-hanger annulus, the grooves 82 in body ring 78 allow such pressure to be exerted to urge body ring 78 inwardly and tubular body 72 outwardly to thereby at least partially compensate for the action of the pressure on the housing and the hanger. It is not generally felt that pressure from within the hanger which is also felt in the upper end of the annulus requires any similar compensation for the relative movement of the hanger and housing responsive to such pressure since the hanger would not move, having the pressure exerted both on its interior and its exterior and the amount of movement of the housing would be accommodated by the action of the seal lips 84 and 86.

A further advantage of the present invention is that it does allow the pressure from the lower end of the annulus to be exerted between body ring 78 and tubular body 72 through the grooves 82 but this is done without sacrificing the relative strength of the structure so that during the setting of seal lips 84 and 86 with setting sleeves, the total structure of tubular body 72 and body ring 78 resist any inward forces developed during such setting. This results from the groove structure but would not result if there were a complete annular space between tubular body 72 and body ring 78 since in such structure body ring 78 would not contribute to resisting the setting loads of the seal lip setting sleeve.

It should be noted that any suitable sealing means, including O ring seals, may be used to seal the closed end of the opening between rings so long as it maintains the seal under all pressure and other conditions to which it may be exposed. Further, the thickness of the rings may be varied from one end to the other to provide the desired structure for each application, as shown in FIG. 5 wherein the improved seal S of the present invention is positioned within annulus A between spool B which is secured to housing H and inner string I which is supported within housing H by sealing and supporting assembly 99. Seal S includes two rings 100 and 102 which are suitably supported by snap ring 103 in position in the annulus between inner member 104 and outer member 106. Seal S also includes inner seal 108 which is positioned in groove 110 on the interior of inner ring 100 and adapted to seal against the exterior of inner member 104 and outer seal 112 which is positioned in groove 114 on the exterior of outer ring 102 and adapted to seal against the interior of outer member 106. This structure makes up sealing assembly 116 which seals across the annulus A between members 104 and 106 and is subjected to pressure which is within inner member 104 and is transmitted into annulus A above sealing assembly 116. Under such conditions pressure is applied from one direction only and the pressure is from within inner member 104 and is exerted both within and around the exterior of inner member 104 above sealing assembly 116. Inner member 104 is thus in equilibrium and will not deflect in the area down to sealing assembly 116 as pressure increases. Outer member 106 which is not in equilibrium will deflect as pressure is applied. A suitable seal is provided between inner ring 100 and outer ring 102 by sealing element 120 which is positioned in groove 122 on the lower interior of ring 102. Ring 100 has a stepped outer surface with upper surface 124 being of a larger diameter than lower surface 126. Shoulder 128 is positioned between surfaces 124 and 126. Ring 102 is provided with an internal configuration including upper surface 130 which is larger in diameter than lower surface 132 and shoulder 134 is positioned between surfaces 130 and 132 as shown. This structure allows the upper portion of ring 102 to be relatively flexible and to easily deflect with pressure between rings 100 and 102. The lower portion of ring 102 being much thicker will not deflect nearly as much because of the relative stiffness of its wall section. Also, at the point of sealing between the two rings 100 and 102, sealing element 120, both rings are relatively thick and will have relatively little deflection which ensures the maintenance of the sealing of element 120 between the members 100 and 102.

What is claimed is:

1. An annular metal-to-metal seal for sealing against the flow of pressure fluid through an annular space between an outer member having an internal cylindrical sealing surface and an inner member having an external cylindrical sealing surface comprising

a first tubular metal ring having a pressure end and an opposite end,

a second tubular metal ring positioned within said first tubular metal ring and having a pressure end and an opposite end,

sealing means on the exterior of said first tubular metal ring spaced from the opposite end thereof,

sealing means on the interior of said second tubular metal ring spaced from the opposite end thereof,

a plurality of longitudinally circumferentially spaced directed passages between said first metal ring and said second metal ring to allow entry of fluid between said metal rings at their pressure end to urge the first and second metal rings into sealing engagement with said inner and outer members, and

means securing said metal rings together in sealed relationship at their opposite ends to block the flow of pressure fluid between the metal rings in the longitudinal passages so that such pressure in the portion of the passages near their sealed ends will urge the unsealed end of the rings apart.

2. An annular metal-to-metal seal according to claim 1 wherein said exterior sealing means includes

a pair of diverging legs extending outwardly from said first tubular metal ring, and

said interior sealing means includes a resilient sealing ring positioned in an annular groove in the interior of said second metal ring.

3. An annular metal-to-metal seal according to claim 1 including

an upper and a lower smaller diameter on the interior of said second tubular metal ring to provide an interference fit metal-to-metal seal therein.

4. An annular metal-to-metal seal according to claim 1 wherein said sealing means includes

an upper interior groove and a lower interior groove,

resilient seal rings positioned in said upper and lower interior grooves, and

an upper smaller diameter on the interior of said second tubular metal ring above said upper interior groove and a lower smaller diameter on the interior of said second tubular metal ring below said lower interior groove to provide an interference fit metal-to-metal seal therein.

5. An annular metal-to-metal seal for sealing across the annular space between inner and outer facing cylindrical surfaces comprising

an outer metal seal ring,

an inner metal seal ring,

an intermediate metal seal ring positioned between said inner and said outer seal rings,

a first longitudinally directed passage between said inner and said intermediate rings and a second longitudinally directed passage between said outer and said intermediate rings, said passages allowing entry of fluid between the rings to urge said inner

and outer metal seal rings into engagement with said inner and outer cylindrical surfaces, and

means securing one end of the intermediate seal ring to both said outer seal ring and said inner seal rings so that the spaces between said rings are sealed at one end which also is opposite the end to which the seal rings are exposed to pressure.

6. An annular metal-to-metal seal according to claim 1 wherein said securing means consists of welds securing said intermediate ring to said inner and outer rings at their respective opposite ends.

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